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SUBJECT: Color Acquisition System Review Study

TASK/PROBLEM

1. Investigate color photography as a possible anticipated intelligence medium. Investigation should cover the capability of present and possible future acquisition systems in an attempt to predict future requirements to support exploitation and data reduction of the collected color photographic intelligence material.

INTRODUCTION

2. Acquisition Altitude: Reference to the acquisition phase is related to the altitudes at which acquisitions occurred or are recommended. Therefore, altitude terms are defined as follows:

a.	Low altitude	less than 5,000 feet (<5M)
b.	Medium altitude	5,000 feet to 50,000 feet (5M to 50M)
c.	High altitude	over 50,000 feet (non-orbital) (>50M)
d.	Very high altitude	orbital condition

Low, medium and high altitudes were defined by the customer.

3. Background:

a. At the outset of work on this project there was little information on the use of color film for photo intelligence purposes. Technical experience of this type with black-and-white acquisition materials was used as a starting point to estimate some of the requirements for color. Later in the program, black-and-white films were relegated to their best role in a color mission; i.e.: as a high resolution medium flown with color in a two-film system.

b. As experience with color increased, more attention was given to the factors which influenced the degree of success possible. These factors include atmospheric conditions, altitude, system capabilities, scene characteristics and intended uses for intelligence effort. While atmospheric effects and end-use of films can now be mentioned throughout the discussion, the initial problem was to examine the effect of acquisition altitude on the photographic response of color films.

DISCUSSION

4. Acquisition Altitude and Film Selection:

a. Good quality color reproduction of ground scenes requires consideration of many factors. Of these, altitude is important because of the scatter of incident light. The degree of scatter apparently depends on the amount of atmospheric interference between the camera and the target. Figure 1 depicts a typical situation where haze is shown as the cause of interference which occurs with altitude. It should be noted that the quantities of image forming light in the red, green, and blue spectral bands are unequal at the camera film plane. The film responds to the image forming light as shown in Figure 2. (Additional discussion is included later in the report.) Figure 3 depicts the acquisition cycle relative to the original ground scene, the aerial image at the film plane, and the various results obtainable by using color films of different contrast characteristics.

b. The film to be used for acquisition should be based on the end use of the processed original. When direct viewing of the camera original is considered as opposed to duplicating as a primary function, different films may be selected for the acquisition phase.

(1) Low Altitude Acquisition: For low altitude, acquisition films must have a low to medium contrast in order to record scenes with wide ranges of brightness within a scene or from scene to scene. Whether the film is a low contrast or a medium contrast will depend on the degree of color realism desired. The medium contrast product will increase the color saturation, thus making discrimination of colored objects easier.

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HAZE ATTENUATION

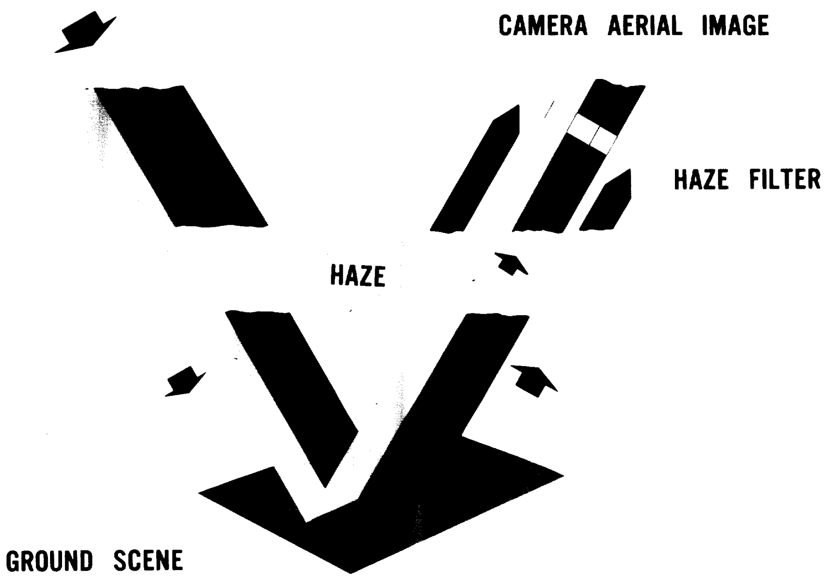

FIGURE 1.

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ACQUISITION ALTITUDE AND FILM SELECTION

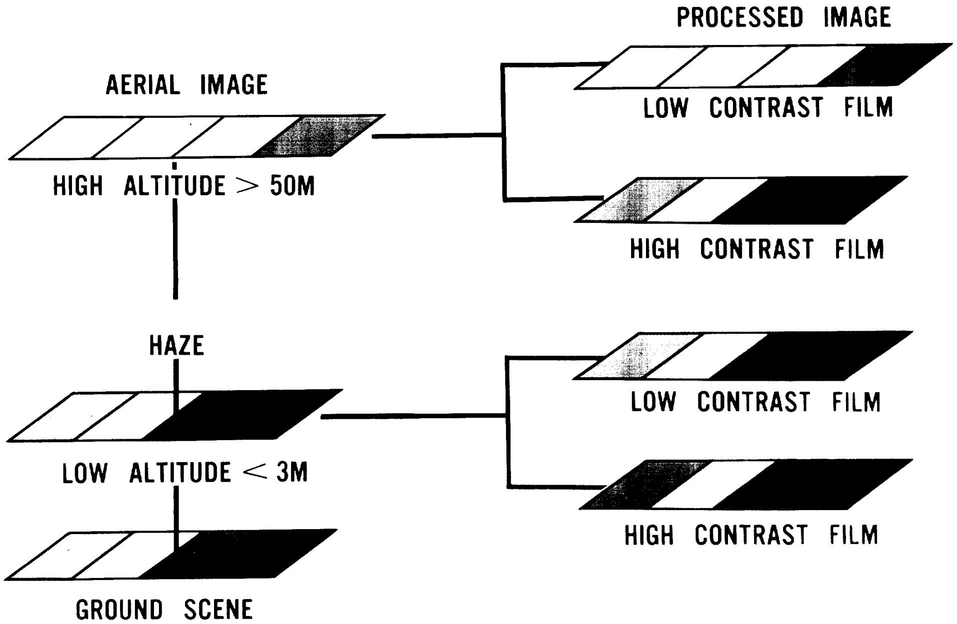

FIGURE 3.

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ACQUISITION ALTITUDE AND FILM SELECTION

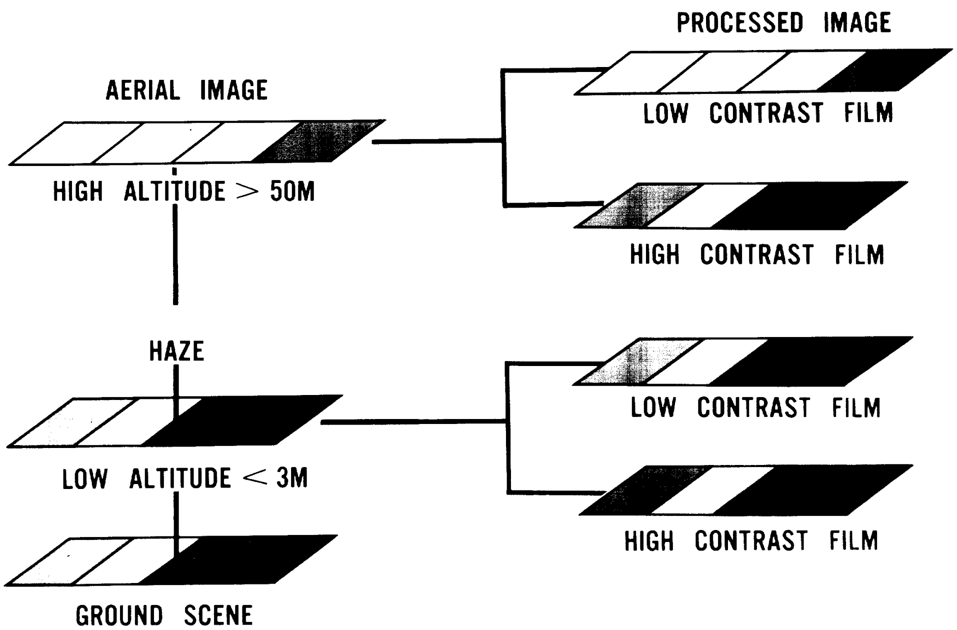

FIGURE 3.

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Photographic speed of the film must also be considered in conjunction with the camera aperture (light gathering power) and the effective shutter speed (to compensate for image motion).

(2) Medium Altitude Acquisition: Investigation of color films for medium altitudes was limited because this altitude region was designated as being of limited tactical reconnaissance usefulness. However, for non-combatant aerial survey or mapping purposes, color films of medium contrast are desirable. By customer definition, medium altitudes range from 5,000 to 50,000 feet, and in this region haze may become the primary factor. Thus the final selection of a medium altitude film must be determined on a local basis by considering the equipment capability, desired altitude, film speed, end product use, and weather.

(3) High and Very Acquisition: At high and very high altitudes, the image forming light is greatly diluted with non-image forming light. Because the film responds only to total light energy, a color film of high contrast must be used to enhance the recording of the image forming light to a useful level in the processed film. High brightness ratios at ground level may be greatly reduced at the camera film plane, giving the overall image an appearance of very low contrast. A high contrast film can be used at high altitudes to amplify the recorded density range of the input image forming light to approximate the original brightness ratio.

(4) Stereo Applications:

(a) Stereo acquisition systems using color film only can achieve excellent results with films selected for low and medium altitudes.

(b) Stereo acquisition systems using color film in one camera and black-and-white film in the other basically follow the above guides. However, end usage of the product for direct viewing or duplication definitely influences the film selection. For direct viewing, either the camera color positive original or duplicate must be viewed with a light intensity at least 4 to 8 times greater than that of the black-and-white side in order to perceive adequate color saturation as well as stereo imagery.

(c) For high altitude acquisition original color positives, the color saturation is so low (even with high contrast films) that direct stereo viewing, especially in conjunction with black-and-white, has limited value for color signature of targets.

5. Color Acquisition Films (Reversal):

a. Definitions:

(1) Reversal Film: When the original camera film is processed in a system where the resulting image has the same appearance as the original object photographed, the film is called a "reversal" film. The advantage of a color reversal film is that no further stages are necessary to produce a positive image.

(2) Speed Concept: The "speed" of a color film is determined by establishing a criteria relative to the particular product group, i.e., color reversal and color negative films, etc. For aerial color reversal products the "speed" is stated as Exposure Index.

$$\text{Exposure} = \frac{1}{2E}$$

Where E is the meter candle seconds of light energy required to produce a density of 1.90. In high contrast color films the "E" values are averaged for the three color sensitive layers to provide a single "E" for the film in question.

(3) Contrast Concept:

(a) The contrast for a color film cannot be described adequately by a single value, although this approach may be useful when considering products with gross differences. A more complete description is provided by using three values. For specific values of "average contrast" of each of the red, green and blue sensitive layers, definite parameters must be employed. Many methods are used. Each can provide useful rather than "correct" values.

(b) For color reversal products, the method employed in this report is the slope of a straight line. One point is plus 0.45 Log E and the other minus 0.45 Log E from the average density of the curve. These two points determine the average contrast for the particular color layer. Color reversal products may be classed generally as follows:

Average Contrast	Contrast Class
0.8 - 1.2	Low
1.2 - 2.0	Medium
above 2.0	High

(4) Product Classes: General classes of color reversal products are of two main groups.

(a) Incorporated Coupler Type

1. These films are those which have the dye forming couplers included in the emlusion during manufacture. This feature permits the use of a relatively simple processing cycle. A typical "incorporated coupler" film process consists of a black-and-white first developer, a means of "reversing" the image, a single color developer and appropriate bleach, fix, and washing cycles. The processes are relatively easy to control and a high level of color fidelity can be maintained. Kodak films with incorporated couplers have the prefix "Ekta" in the name. Ektachrome is an example.

2. Many films of this group can be processed in the field by use of chemical kits available from the film manufacturer.

It is imperative that the instructions supplied both with the film and the chemical kits be rigidly followed in order to attain the best quality. There are some "incorporated coupler" films which must be returned to the manufacturer because facilities for processing are not yet generally available.

(b) Unincorporated Coupler Type

1. These films do not have the dye-couplers incorporated during manufacture. The couplers are, instead, included in the color developer solution formula. The resulting process is therefore more complex.

2. A typical commercial process of this type includes a black-and-white first developer, three individual color developers (one for each emulsion layer in the film), three separate means of re-exposing the individual layers, plus bleaching, fixing and washing cycles. Because color developer solutions require addition of the color couplers in the mixing stage, both chemical mixing and the subsequent processing operation must be carefully controlled. These complications reduce applicability to field type systems. The Kodachrome films are typical of the "unincorporated coupler" type.

b. The Reversal Films

(1) Types: Types of color reversal film available and/or successfully tested to date are:

(a) Kodak Special Color Film (Estar Thin Base), Type SO-121: Incorporated Couplers.

(b) Kodak Ektachrome Aero Film, Type 8442: Incorporated Couplers.

(c) Kodak Special Ektachrome MS Aerecon Film, Type SO-282: Incorporated Couplers.

[redacted] 25X1

Incorporated Couplers.

(e) Kodachrome II for Daylight: Unincorporated Couplers. Acquisition flights were made with all films listed above except Type 8443*. Types 8442 and SO-121 have been flown at high altitudes (60,000 to 70,000 feet) with good to excellent results. In these cases the prime use of the camera original was for the reproduction of second generation color positive duplicates.

(2) Resolution: Equipment and altitude during acquisition resulted in different ground resolutions. Relative resolution values of the camera-film-atmospheric conditions are shown in Table 1.

(3) Scale: Camera lens system and altitude will determine the scale of the photographic image. Examples for systems now in use are:

System	Altitude	Approximate Scale
B Camera	70,000 feet	1:23,000
Delta II	70,000 feet	1:35,000
"J" System	100 miles	1:264,000
"G" System	100 miles	1:82,000

"G" system photography is at about the limit of scale where current color materials can be considered useful.

* After this investigation, a flight was made with Type 8443 on 18 August 1965. The limited particulars from this one test are given in an addendum to the appendix.

TABLE 1

System Resolutions for Color Acquisitions

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Film	Altitude	System
Kodak Special Color Film (Estar Thin Base) Type SO-121	6,000 feet) 12,000 feet)	Twin Maurer
	67,000 feet)	Delta II
Kodak Ektachrome Aero Film Type 8442	67,000 feet	B Camera
Kodak Special Ektachrome Aero Film, Type SO-282 (MS)	6,000 feet) 12,000 feet)	Twin Maurer
Kodachrome II for Daylight	Approx. 95 miles	"G"

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* It is essential to point out that many factors influence ground resolution; the film used is only one. Therefore, the ground resolution shown is a system result and is not necessarily limited because of the film used.

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(4) Color Balance: Color Balance of the original color positive may be "unnatural" in some cases because of unpredictable haze levels as well as uncertainty of the exposure level for the scene brightness ranges recorded. These balances were corrected in subsequent duplicaitng stages. The degree of color fidelity corresponding to the actual scene must at this time be established subjectively. Figure 3 is indicative of the method of film selection versus desired total contrast, while Figure 2 indicates the effect of selective contrast for each color. A refinement of the approaches to color balance problems is set forth later in paragraph 9, "Attenuation by Haze."

6. Acquisition Films (Color Negative):

a. Color negative films suitable for acquisition systems can generally be used only at low altitudes because of resolution limitations. High altitude tests were not scheduled because of this. However, color negative materials should be considered for future testing if available films are improved.

b. A color negative film for acquisition is available. It must be considered only as a part of a negative-positive system. The camera color original is unreal in visual appearance in that the target is presented in complimentary colors; e.g., a red car will appear blue-green on the negative which will in turn be further distorted by a built-in orange-yellow mask. A color negative-positive system is similar to black-and-white except that dye images are developed instead of silver images. Color negative and print materials usually have incorporated dye couplers. Processing is relatively simple, consisting primarily of a color developer, stop bath, bleach, fix, and the necessary washes. Processed color negative images will be of little value to the photo interpreter because of their unreal appearance as cited above. The complimentary color dyes used are

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designed for compatible print material, not the human eye. Reliable identification of target colors by direct examination of the negative should not be expected. Target images, of course, can be discerned to save time in the selection of frames for printing.

c. The type of color negative product available is identified as Kodak Special Ektacolor Aerial Film, Type SO-276.

7. <u>Special Color Acquisition Film</u>:

a. Special color materials are commercially available. These have been designed for acquisition of data in an unreal image. [redacted] is the prime type. The material is a color reversal type where the positive-image colors are false for most living vegetation. The usefulness of this product is greatest in detecting the difference of living, partially living, and dead vegetation in forest surveys and camouflage detection.

25X1

25X1

b. A review of the applicability of color for moving target identification (MTI) film was made. Color products of this type are <u>not</u> currently available although some research work has been done. Because of the rapid access requirement for an MTI system, it can best be accomplished at present with available black-and-white products used in conjunction with special viewing equipment. The entire system can be airborne and information relative to the moving targets located can be communicated immediately to tactical ground support units by radio.

8. <u>Technical Data</u>: Technical data are included in Tables 2 and 3 to provide guides for the selection of acquisition materials. Photographic characteristic curves and additional data are included in the appendix.

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GROUP 1
EXCLUDED FROM AUTOMATIC DOWNGRADING AND DECLASSIFICATION

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Tables 2 and 3 For

Selection of Acquisition Color Films

Final determination of which color film to use for a specific mission can be accomplished by using these data plus the product characteristic curves shown in the appendix. A suggested method is outlined by the following steps.

a. Determine the approximate acquisition altitude relative to the ground.

b. Select those films which are within the altitude ranges indicated in Table 3.

25X1 c. Using the [redacted] Aerial Exposure Computer," determine the solar altitude of the target area as a function of date and latitude.*

d. Using the computer, determine the parameters of camera capability.

e. After complete determination of camera-film combination select the film with the best resolution.

While processing of the film was not included as a step in the final selection, this factor should not be overlooked. Requirements for accessibility to originals and for duplicates must be determined on a local basis.

*NOTE: Exposure of aerial color film is not recommended at solar altitudes of less than 30° until further data becomes available. This is because of increasing effects of haze on color balance at the lower solar altitudes. Further discussion of this immediately follows Tables 2 and 3 under paragraph 9, "Attenuation by Haze."

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Table 2

Table of Product Contrast

The average contrast is measured as slope of a straight line connecting the points plus 0.45 Log E and minus 0.45 Log E from the average density of the photographic curve for each spectrally sensitive layer.

Product	Contrast of Spectrally Sensitive Layer: Red	Green	Blue	Average Contrast*
Kodak Special Color Film, (Estar Thin Base) Type SO-121**	2.12	2.28	2.50	2.30
Kodak Ektachrome Aero Film, Type 8442	2.73	2.85	2.65	2.74
Kodak Special Ektachrome (MS) Aerecon Film, Type SO-282	1.60	1.78	1.73	1.70
Kodachrome II For Daylight	2.30	1.95	2.22	2.16
Kodak Ektacolor Aerial Film, Type SO-276	0.62	0.60	0.78	0.67

25X1

* The use of "average contrast" must be limited to general discussion only. For tone reproduction and/or estimation of recorded Log E and color balance, each layer must be considered individually.

** Data for Type SO-121 is based on measurements of a recent sample of this material.

TABLE 3

Usability Data for Kodak Acquisition Materials

Product Name	Kodak High Definition Aerial Film SO-121	Ektachrome Aero Film Type 8442	Special Ektachrome MS Aerecon Film SO-282	Kodachrome II Daylight
Special Application	For medium to high altitude acquisition.	For medium to high altitude acquisition.	For low to medium altitude acquisition.	Usable for high altitude acquisition.
Aerial Exposure Index	13 (estimated)	25	6	2.5 to 3.0
Resolving Power (lines per millimeter)	>10:1 151 / TOC* 1.6:1 76	>10:1 100 / TOC* 1.6:1 32	>10:1 75 / TOC* 1.6:1 40	>10:1 119 / TOC* 1.6:1 63
RMS Granularity	0.0198	0.0820	0.0390	0.0100
Modulation Transfer Function (limited test data) 50 l/mm	30%	7%	11%	75%
100 l/mm	5%	0%	0%	7%
Special Lens Requirements	Full color correction	Full color correction	Full color correction	Full color correction
Filter Requirements	2E	2B	Probably 2B - Needs testing	Probably 2B - Needs testing
Overall Thickness	3.5 mils	6.1 mils	6.0 mils	5.8 mils
Antihalation Backing	Dyed Pelloid	Undercoat	Undercoat	Rem-jet

*Test Object Contrast

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TABLE 3 (Cont'd.)

Usability Data for Kodak Acquisition Materials

Product Name	Kodak High Definition Aerial Film SO-121	Ektachrome Aero Film Type 8442	Special Ektachrome MS Aerecon Film SO-282*	Kodachrome II Daylight
Overall Splice Thickness Tape	8.5 mils	11.1 mils	11.0 mils	10.8 mils
Weld	4.5 mils	Does not apply	Does not apply	Does not apply
Leader Requirement Trailer Requirement Size (Width and Length) Edge Printing	Customer Specification	Customer Specification	Customer Specification	Customer Specification
Max. Film Transport Speed (Corona discharge) Acquisition System Adaptability	Info unavailable	Info unavailable	Info unavailable	Info unavailable
Processing	Mfg. Recommendation	Mfg. Recom.	Mfg. Recommendation	Mfg. Recom.

* Kodak Special Ektachrome MS Aerographic Film (Estar Base) Type SO-151 has the same characteristics except the overall thickness is about 4.8 mils.

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9. Attenuation by Haze:

a. Terminology: Aerial photography is more complex with color film than with panchromatic film. Chiefly, this is because of the changes in atmospheric conditions which alter the relative quantities of red, green, and blue light striking the film plane at high altitude. The investigator is concerned with both the total amount of light energy in each spectral band and the more important percentages of total energy in each band which are image forming (see again Figure 1). The change in atmospheric conditions is generally called variation of haze. This term "haze" refers to the combined effects of dust, moisture droplets, water vapor, etc., in the atmosphere.

(1) Atmospheric haze is a condition which prevails over a very wide geographical area and has been subjectively classed as light, normal and heavy. Percentage values are assigned; however, the basis for such values must be carefully defined.

(2) Industrial haze refers to an additional concentration of light scattering or absorbing particles, generally limited to a small geographical portion of the area being photographed. Haze of this type is typically smoke and industrial gasses reacting with the atmospheric moisture to form a light scattering medium. Localized ground fog may be a combination of both industrial and atmospheric conditions.

b. Effects and Characteristics:

(1) The effects of haze are paramount in color aerial photography. The proportions of image forming light which reach the acquisition system after passing through the atmosphere are among the more critical factors. These are expressed as percent transmissions. The transmission values for extremely clear air from 65,000 feet altitude are approximately:

Red (600-725 mμ): 87%
Green (470-610 mμ): 85%
Blue (410-510 mμ): 69%

The percentage of image forming light as seen at the film plane will, of course, be reduced with an increase in haze concentration.

(2) Values have been reported by investigators which differ from those above. The usefulness of these data on a practical basis is in the selection of the color film to be used and the resultant visual color balance distortion of the processed image. By selecting a film which has relative primary color contrasts inversely proportioned to the transmissions and properly selecting the exposure, a well balanced image will result. Earlier, Figure 2 showed the effect of such a relationship in which the lack of equal quantities of image forming light has been "corrected" by contrast relationships in the color acquisition film. Figure 4 is an extension of this ideal approach to a realistic set of typical characteristic curves for high altitude color reversal film. Figure 4 also demonstrates a degree of tolerance for color balance accommodation by the observer. It further depicts the necessity of using films with different characteristics at different altitudes.

c. Solar Altitude and Vehicle Altitude:

(1) The maximum effects of haze-solar altitude combinations are observed when solar altitudes are less than 25°. At low solar altitudes there appears to be an increase in the diffraction effects of the atmosphere for which exact rates of change are unknown.

(2) Increasing acquisition altitude from ground level to high altitude incorporates a constantly increasing effect of non-image forming light. The change, however, is not a linear function. The result will be observed in the processed original where the scene brightness ratio

FILM LATITUDE

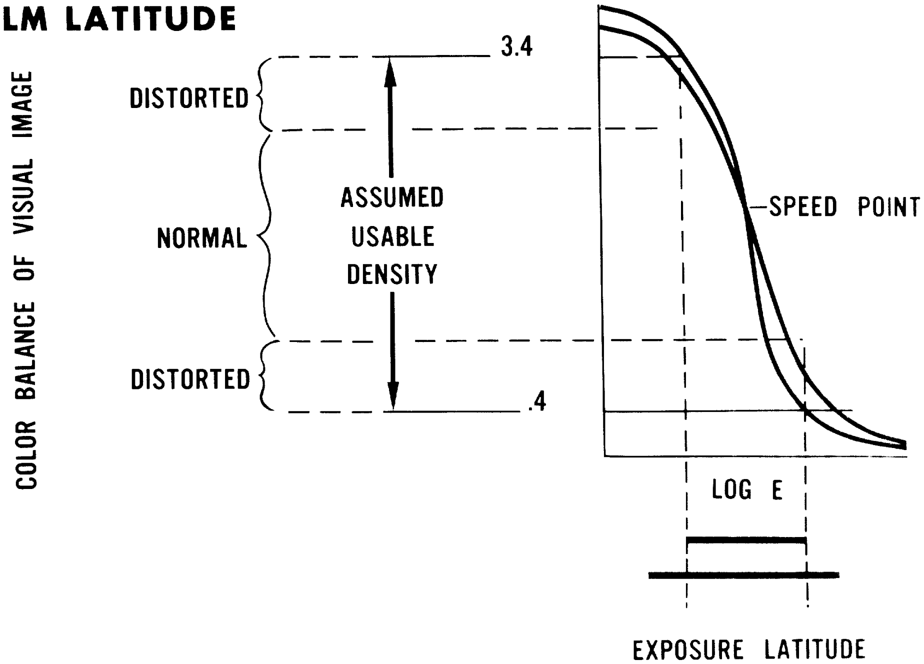


FIGURE 4.

has gradually been reduced and a color balance shift becomes evident (see Figure 3). There is no color film made which will accommodate and retain true color fidelity for all conditions of haze and scene brightness. Thus, color balance must be optimized by proper camera exposure and film selection.

(3) Correlating color balance shifts and haze as a function of vehicle altitude cannot be accomplished at this time. An infinite number of haze-altitude combinations exist. These are being explored only at altitudes of major interest. The haze concentration determines the absolute relationship of image forming and non-image forming light striking the film. At different haze-altitude conditions, a given scene will be recorded at different color balances even though the camera exposure setting has been adjusted to provide passage of the same <u>total</u> light energy. Additional study should indicate the corrective steps required for various weather conditions and altitudes.

10. Collection Systems

a. Design Requirements: Specific operational and experimental collection systems have some common areas of design which contribute to the potential usage of color films.

(1) Lenses should be color corrected for sharpest focus at the film plane for spectral bands within the visible spectrum for "true" color acquisition systems. For "false" color systems the lens should provide good imagery and transmittance for the spectral bands of interest.

(2) Methods of incorporating haze and/or color correction filters are essential.

(3) Systems capable of simultaneously exposing different film types require independent control of exposure for each film to provide a means of compensating for different Exposure Indexes.

(4) Systems capable of exposing black-and-white which may

have color film spliced in for successive expousres must also have methods of programming different filters into the light path for color and exposure correction of the color sequence; otherwise, optimum quality cannot be attained.

(5) Color emulsions are thin enough to be within the depth of focus of those lens systems now in use, at least, those systems of which the contractor is aware. This implies no design requirement; however, depth of focus should be considered in designs for any future systems.

b. System Factors Affecting Quality

(1) Lens data is limited for potential color acquisition systems. Data on lens transmission and resolution are needed to predict the potential usefulness of color films. Acquisition tests to date do not indicate that maximum resolution of a color film has been reached.

(2) Adaptability of color acquisition films must be analyzed on a system basis which includes not only the design considerations mentioned above but also type of mission, high or low altitude, end product usage, product finishing or processing, and access time permitted to obtain the processed film.

11. Filters for Color Acquisition Films

a. Filter Types and Usage: Two types of filters have been used commonly in testing acquisition color films at various altitudes. These are the haze cutting type and the color correction type.

(1) Haze cutting filters are used to reduce the effect of unwanted blue light caused by atmospheric scattering of incident and reflected light on a ground target. All films responding to the visible spectrum (both color and black-and-white) have a sensitivity to the ultra-violet and blue portions of the spectrum. By using a haze filter such as a Wratten 2B or 2E the blue sensitive layer is exposed at a higher ratio

of image-forming to scattered blue light. This improves the color balance of the processed image. Characteristics of haze filters are published in "Kodak Wratten Filters for Scientific and Technical Use", Eastman Kodak Company, 1965. Pertinent data from this source is shown in Figure 5 for the 2B and 2E filters.

(2) Color correction filters have been employed where the product tested required a shift in photographic speed of one emulsion layer with respect to the others. The reasons for using these filters were to:

(a) Obtain data relative to a particular film.

(b) Adjust the relative emulsion speeds for an anticipated haze-altitude condition.

(c) Follow the manufacturer's recommendations for the specific product where a small color balance change was considered desirable for product usability.

b. <u>Test and Experiment Parameters</u>

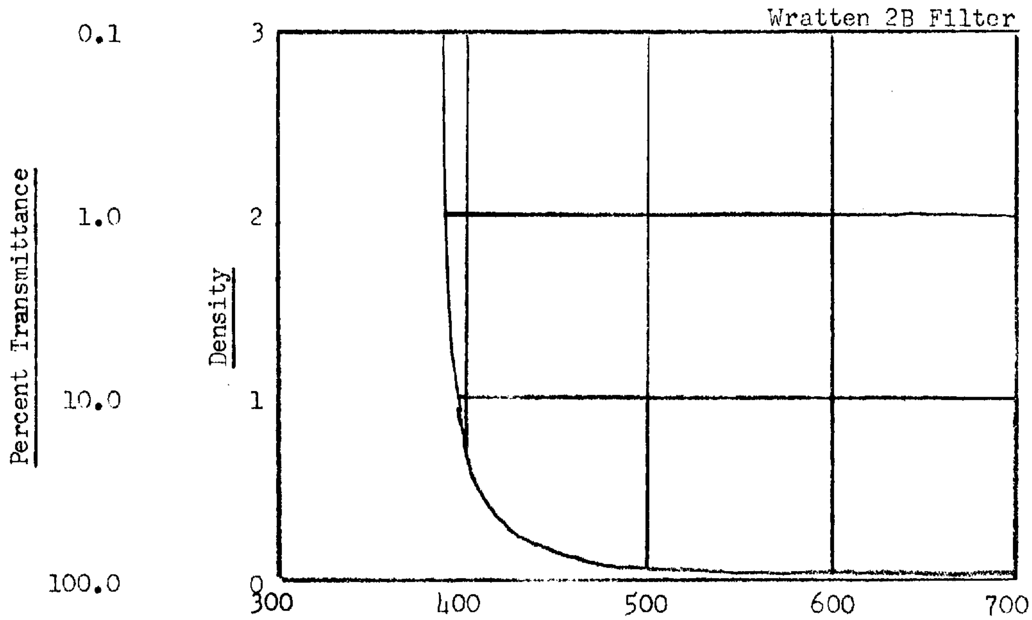
(1) The effects of a given filter system used with a color film should be laboratory tested prior to flight. The process should be that recommended by the manufacturer. Testing is simply accomplished by making sensitometric exposures of a gray scale Calibrated 25X1
No. 3 Step Wedge) with the light source corrected to a daylight equivalent plus the proposed filters. The sensitometric results of this test are than used for final camera setup prior to the mission.

(2) During flight testing no attempt was made to intentionally bias the acquisition color original to a specific customer's color balance.

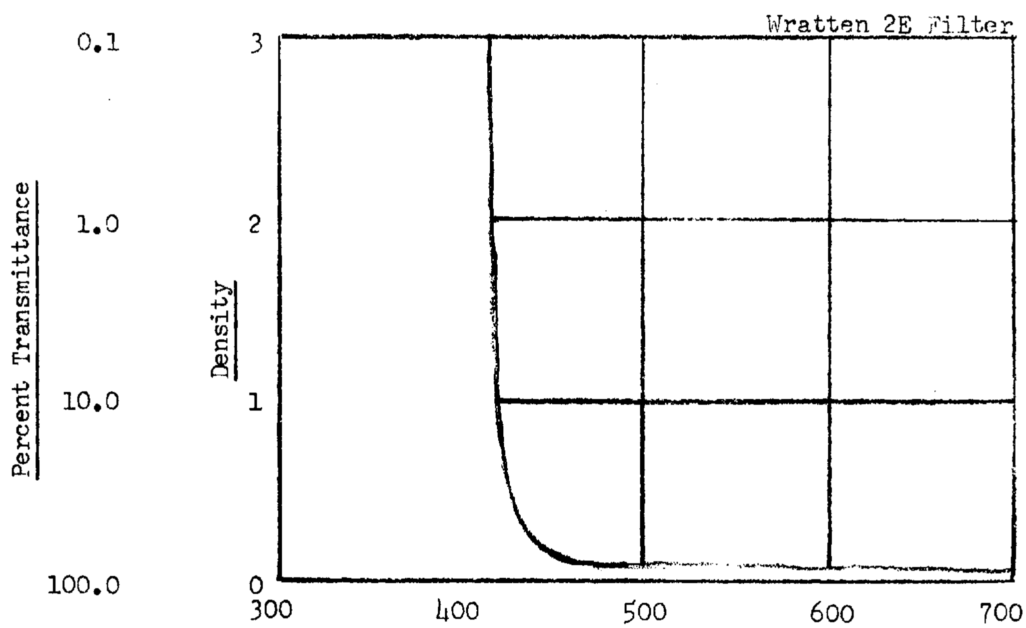
(3) Use of color filters for exploration of the processed acquisition color films was limited to "Color Correction" filters for

Figure 5

Transmittance Versus Wavelength
for 2B and 2E Haze Filters



WAVELENGTH:	400	410	420	430	440	450	500	600
% Transmittance 2B:	19.0	48.0	67.0	75.9	80.0	83.0	89.5	91.1
% Transmittance 2E:	- -	- -	8.7	51.1	75.8	82.2	89.0	90.7



guidance in the subjective analysis of the original during the duplicating stages (see PAR 213, Final Report).

12. Exploitation of Processed Color Acquisition Film

a. Viewing Conditions: For optimum exploitation of processed color films, viewing must be accomplished under carefully controlled conditions. While eye accommodation will quickly normalize the colored image to each observer, comparisons will be more difficult if two illuminators are used which have different color temperatures and intensities.

b. Viewing Methods and Effects

(1) Viewing a color positive original by itself will give the impression of full color gamut. If taken at high altitude it will appear low in contrast. If the original is examined with a magnifier (7X to 20X), the images will appear to have higher density ranges. This effect is caused by the viewer restriction in the area observed.

(2) Stereo viewing of high altitude color positives with black-and-white will give the impression of stereo with low color saturation. The saturation is too low for rapid identification of color targets. Thus, best color black-and-white/stereo imagery requires either a high contrast color original image or a high contrast color duplicate image. Attempts have been made to view the color positive originals and black-and-white negative originals in stereo. Stereo imagery can be seen but with extreme difficulty and with poor color saturation. The idea has little practical value even for a "quick look" examination.

c. Other Information: For a complete summary of viewing equipment and its use, the reader is referred again to PAR 213, Final Report, "Color Reproduction Systems Review," 15 April 1965, [redacted] 25X1

CONCLUSIONS

13. Color films are available and have been tested at all altitudes of

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interest.

a. Color reversal films were tested at high, and very high altitudes. Orbital testing has been extremely limited.

b. Color negative films for acquisition purposes are designed primarily for low altitudes. High altitude tests have not been accomplished because of the relatively low resoltuion of available color negative films.

14. Excellent color originals have been attained at low altitude. Good color originals were also obtained at high altitude, but required some correction for optimum color balance in the duplicating phase.

15. Aerial exposure selection is more critical for color than for black-and-white films, because the exposure range over which the three emulsion layers are balanced is shorter than that of a black-and-white film of the same contrast. Exposure is most critical at high altitude where unpredictable haze/solar altitude combinations can produce unnatural results.

16. At high altitudes haze attenuation relative to spectral distribution of image-forming light has yet to be adequately defined for all atmospheric conditions.

RECOMMENDATIONS

17. Conduct a series of test flights under various conditions of haze to enlarge existing knowledge of these conditions as they affect contrast and color balance.

18. Conduct low altitude flights using color negative film.

19. Evaluate infrared color film at high altitude.

20. Authorize limited operational acquisitions over selected target areas using Type SO-121 color reversal film.

21. Continue studies of stereo systems using color in conjunction with black-and-white.